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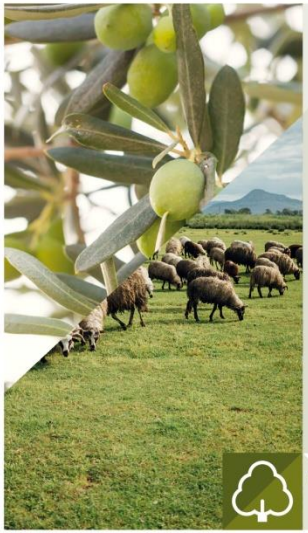

Module 1 – Agroforestry for Multifunctional Olive systems

Course 2 - Agroforestry Systems on Olive Orchards Soil Management

Chapter 2 – Intercropping with olives

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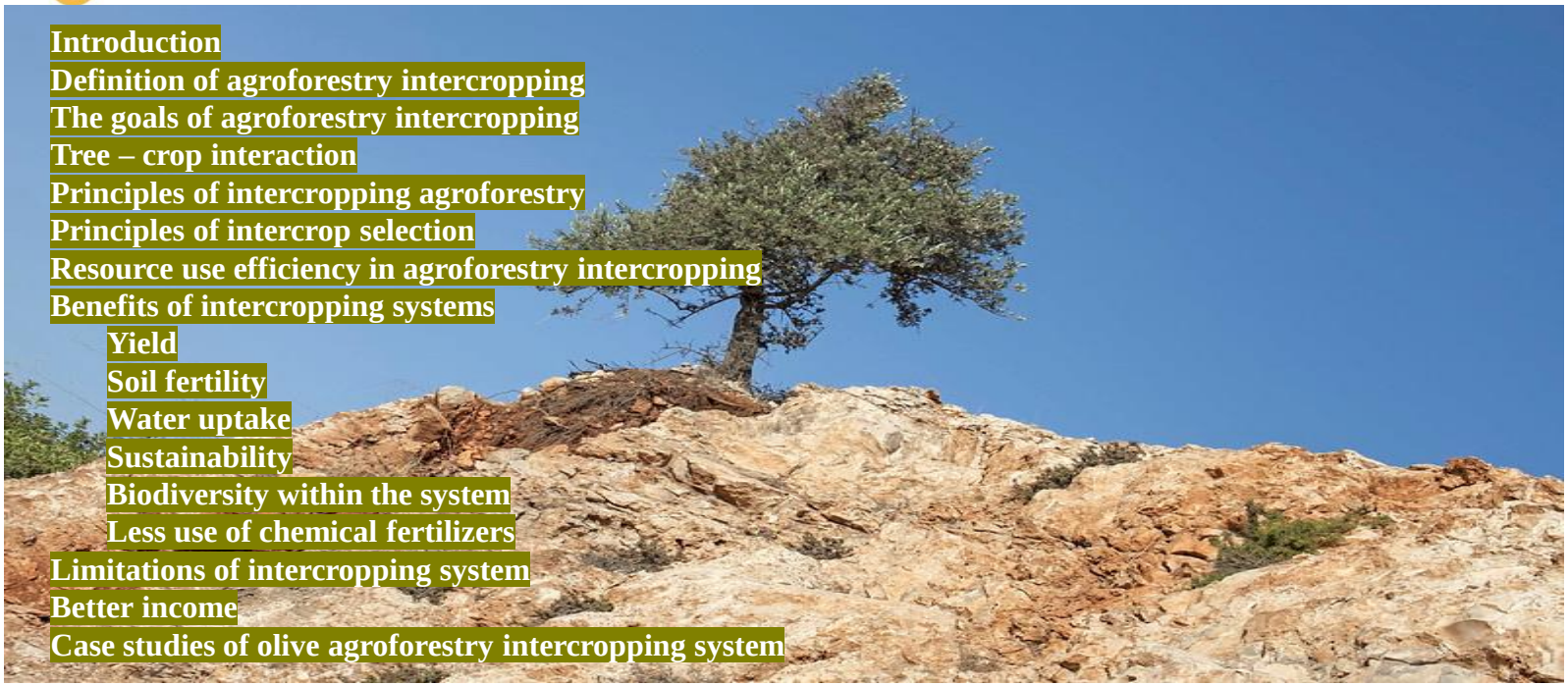
Content



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Introduction

- Historically, intercropping evolved spontaneously when humans struggled to diversify their sources of income and food from the land they cultivated in the absence of technological advancements that were not available at that time
- With the beginning of the industrial revolution, agriculture underwent a radical transformation, leading to the emergence of what is now known as modern agriculture
- Despite the fact that modern agriculture has increased production to meet the increasing human demand for food, it brought negative environmental consequences that have been manifested in the deterioration of soil fertility

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Introduction – Soil function

- Soil functions:
  - Nutrient cycling
  - Carbon storage and turnover
  - Water dynamics
  - Promotion and regulation of biodiversity and habitat
  - Filtering and buffering
- Soil degradation is the decrease of soil's ability to perform some of its functions

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Introduction – Soil function

- Nutrient cycling

Soil provides an appropriate environment for the decomposition of plant and animal remains into minerals

The minerals can be retained in the soil, lost to air and water, and/or used by plants as food for humans and animals

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Introduction – Soil function

- Carbon storage and turnover
  - Carbon is removed from the atmosphere and stored as soil organic matter (SOM) in the soil. This process is mediated by the plant through the process of photosynthesis, which converts solar energy into organic molecules
  - The decomposition of plant biomass by soil microbes results in the loss of carbon as CO_2 from the soil via microbial respiration. During the decomposition process, only a small proportion of C is stored in soil as humus.

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Introduction – Soil function

- Water dynamics. Soil can regulate the infiltration, flow and storage of water which carries sediment, organic matter, plant nutrients such as nitrogen and phosphorus, pesticides, and other dissolved or suspended compounds
- Promotion and regulation of biodiversity and habitat. Soil supports the growth of a wide range of plants, animals, and soil microorganisms, usually by providing a diverse physical, chemical, and biological habitats
- Filtering and buffering. The soil absorbs potentially harmful elements and compounds from the air and water, such as heavy metals and pesticides. Some of these compounds are utilized and degraded by soil microorganisms, while others are physically held in soil pores and chemically on the cation exchange site

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Introduction – The important of agroforestry

The increased use of chemical fertilizers, pesticides, and herbicides in modern agriculture, as well as frequent soil tillage and the use of heavy machinery, have led to ecological imbalance

One of the main reasons for the decline in rural sustainability is farmers' inability to compete with modern agriculture, which forces them to neglect their orchards

Pillars of sustainability

- **Economic**
- **Social**
- **Environmental**

In light of these adverse impacts, there is an urgent need to investigate alternatives to intensive agricultural practices

Therefore, the tendency towards reviving the agroforestry systems due to their economic, environmental and social benefits, has been the subject of extensive studies for many years

Definition of intercropping agroforestry

- The practice of growing any economic crop in alley spaces of the fruit trees in the first few years or in the unoccupied spaces of the long duration crop in the early periods is referred as **intercropping** (N. Kumar. 1997)
- "**Intercropping** and agroforestry are mixed plant species cultivation systems that can potentially reduce pressure on land and water resources by generating higher crop yields and by increasing resource use efficiencies through exploitation of complementarities between species" (Yu Hong et al. 2017)
- **Intercropping** is defined as the agronomic practice of growing two or more crops on the same field at the same time (S. Asseng et al. 2014)

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The goals of intercropping agrofrestry

- The goals of intercropping in agroforestry system are to:
  - Efficiently exploit environmental and land resources (light, water and nutrient), as the efficient use of these resources underlies maintaining soil fertility and reducing soil erosion
  - Maximize profitability by utilizing available space in orchards
  - Ensure economic stability or safety in case one of the crops failed due to many factors, especially in olive orchards where the tree experience alternate bearing phenomenon
  - Diversify farmer incomes and improve land use sustainability, particularly in marginal regions with fragile ecosystems, water scarcity, and unsustainable exploitation of natural resources
  - Provide social benefits to both the land-holder and the surrounding community

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Tree-crop interaction

- Interaction is defined as the effect of one component of a system on the performance of another component and/or the overall system (Nair, 1993). Thus two important questions may be raised:
  - How the components of intercropping system utilize and share the resources of the environment?
  - How the growth and the development of any of the component will influence the others?
- The management of the interactions between agroforestry components is the heart of successful agroforestry practice. The role is to minimize competition for light, water and nutrients among different components
- The proper function of intercropping in agroforestry system is conditioned by:
  - The availability of environmental resources
  - The ability of the intercropping system component to share these recourses

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Tree-crop interaction

Types of interactions

Complementary

When the production of both the tree and the crop increases simultaneously

Supplementary

The yield of one component (tree) increases while the yield of the other component (crop) remains the same

Competitive

When the yield of one component increases, the yield of the other component (crop) decreases

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Example of complementary interaction

Olive orchard intercropped with winter wheat

The growth of the olive tree is not impaired by the growth of the winter wheat. During the winter and early spring, the olive tree grows slowly and is unaffected by fast-growing wheat. To ensure the effectiveness of this system, it is necessary to avoid overlapping the maturation of wheat plant with the vegetative and reproductive growth of the olive tree

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Tree – crop interaction

Positive effect

- Modified environment under the tree shade. Trees in the intercropping system reduce the evaporative demand of the crop by lowering wind speed, moderating temperature, and increasing humidity
- Pruning materials, leaf litter, and root residues add N and OM, improve soil conditions and increase productivity of the agroforestry intercropping system
- Litter with high C/N ratio (high lignin and polyphenolic content) that decomposes slowly acts as mulch which maintains soil moisture during the dry season
- The root system of the tree pumps from deep soil layers nutrients that have been leached from the top soil and liberated from weathered minerals
- Intercrop vegetation and tree canopy help to minimize erosion
- Fast growing intercrop and tree canopy suppress weeds
- Multi-species agroforestry system reduces pest and disease pressure by facilitating natural biological control

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Tree – crop interaction

Negative effect

- Competition for light. The growth of plants depends on photosynthesis. Therefore the light is considered the most limiting factor for intercrop growing in close proximity to the tree (Shading effect)
- Tree shade can prevent light from reaching the plants, especially in dense evergreen orchards. Low light intensity is one of the important limitations in increasing yields

Photo by Dr. Peter Moubarak

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Tree – crop interaction

Negative effect

- Allelopathy. Allelochemicals released in environment and rhizosphere under appropriate conditions affect neighboring plants
- Some root exudates are toxic to the root of other crop (e.g. barley exudate substances inhibit the growth of lettuce)
- Soil sickness is caused by the accumulation of phytotoxic substances released from the roots of plants that have been cultivated for a long time in the same place. Mono-culture is the main cause of soil sickness
- Trees and crops can spread pests and diseases to one another
- Host plants of fungal disease (*verticilium*) grown as intercrop in olive orchard: celery, eggplant, lettuce, melon, pepper, potato, pumpkin, squash, tomato, and watermelon

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Tree – crop interaction

Negative effect

- The limited soil nutrient pool, increases the competition between the tree and the crops
- The shallow fine root system developed by tree competes for water and nutrient with the root system of the intercrop. Even though trees have developed root systems that grow deep into the soil profile, they preferentially (most active in water and nutrient extraction) access water from surface zones when it is available
- The impact of this competition on both tree and crop varies according to rainfall and nutrient availability
- Roots often extend to great depths in freely drained soils, and are only shallow where soil conditions restrict root growth (e.g. A compacted layer at a shallow depth that restricts root growth may provoke greater competition between tree and crop root systems). This issue may be more dramatic in rain-fed orchards

Principles of intercropping agroforestry

- The following primary principles should be considered when implementing intercropping systems:
  - Fruit trees are the primary crop in agroforestry
  - Plant morphology and physiology
    - Type of tree: Evergreen / Deciduous
    - In evergreen orchards, the trees are usually pruned to have light canopy that allows sunlight to pass through to the intercrop
    - Crops with deep root system can compete with trees for water and nutrient
    - Barley, groundnut, pigeon pea, sorghum, sunflower, sweet potato and wheat are great intercrops
    - Intercrops that have tendency towards excessive growth should be avoided otherwise they can exhaust the nutrient and moisture from the soil
    - Avoid synchronizing growth stages of crops and trees
    - Moreover, the maturity of the intercrop should not coincide with the critical stages of tree growth (flowering, fruit growing and maturity).
  - Crops should be short duration and quick growing.

Principles of intercropping agroforestry

- Cultural considerations
  - The selected intercrop for agroforestry system should not hinder the implementation of agricultural operations in the orchard
  - Some perennial crops are considered unsuitable in agroforestry, because their permanent presence in the orchard will impede agricultural operations, especially harvesting
  - Crop rotation is an important agricultural practice to reduce the pressure on soil nutrient reservoir, prevent the building up and spreading of soil borne diseases, and improve soil physical attributes
  - Avoiding soil erosion through vegetative cover, reducing competition for nutrients with trees, and achieving economic yield are the main desired goals when choosing planting density
  - Avoid planting intercrop in area where the roots of the fruit trees are concentrated

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Principles of intercropping agroforestry

- Allelopathy and disease outbreak
  - Negative allelopathic effects of agroforestry components on each other should be negligible
  - Incorporating intercrop into an agroforestry system should aim at reducing pest and disease outbreaks by providing a suitable habitat for natural enemies
  - It is recommended to leave strips or spots of spontaneous vegetation in the orchards to improve pest control in the intercropping system, since intercrop alone is not enough to provide habitats for natural enemies especially in semi arid and arid regions where water is scarce
  - Radish, roquette, turnip, squash, or natural vegetation (wild groundsel), as well as buckwheat/carrot, are all incredibly attractive to important groups of natural enemies (Hymenopterous parasitoids, Coccinellidae, Syrphidae, Anthocoridae, Chrysopidae) (Annette Herz et al., 2005)
  - Avoiding intercrops that attract aphids, whose honeydew is an important source of food for the olive fruit fly
  - Intercrop can be at the same time a shelter for pest and beneficial insects

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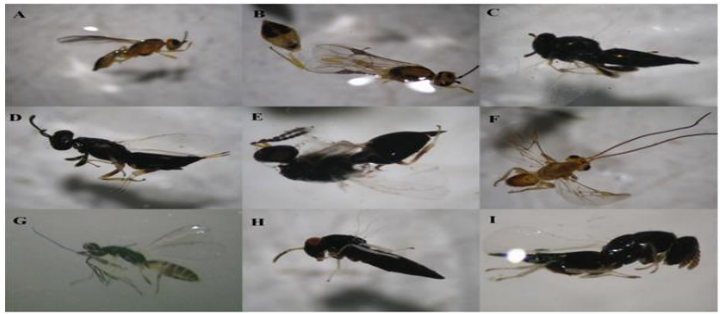
Principles of intercropping agroforestry

- Allelopathy and disease outbreak

Hymenopterous parasitoids olive fruit fly found in Lebanon (Abdel Kader El-hajj et al. 2018)



Figrue1.Isolated parasitoids from olive fruit samples: (A) (B) *Bracon* sp.,(C)) *Cyrtoptyx dacicida*,(D) *Eupelmus urozonus*,(E) *Eurytoma* spp., (F) *O.concolor*,(G) *Pnigalio meditterranean* (H) *Pteromalus*, (I) *Tetrastichus* sp

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Principles of intercropping agroforestry

Inula viscosa

Buckwheat

Arugula

Leo Michels, Public domain, via Wikimedia Commons

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Principles of intercropping agroforestry

- Economic considerations
  - The selected intercrop should have marketability and not be subject to competition from monoculture
  - Availability of labor
- Climatic considerations
  - The harsh climatic conditions make the implementation of intercropping somewhat difficult
  - The choice of intercrop depends mainly on the prevailing climatic conditions in a particular region
  - Autumn and winter in Mediterranean areas are cold and rainy, with low evapotranspiration rates. Spring and summer, on the other hand, are hot and dry with high evapotranspiration rates
  - These prevailing weather conditions of the Mediterranean area allow olive farmers to introduce winter crops in their orchards due to high water availability that sustains most crop stages during autumn and winter seasons

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Principles of intercropping agroforestry

- Species type
  - Preference should be for crop species that offer greater soil erosion control
  - Cereals (wheat, barley) and legumes (faba bean, lentils, peas and winter chickpea)
  - Aromatic and medicinal species encourage bees and other pollinator species
  - Edible vegetation for gourmet markets: Arugula (*Diplotaxis* spp.), sow thistle (*Sonchus oleraceus*), wild chicory (*Cichorium intybus*), and perennial wild asparagus (*Asparagus acutifolius* L.)

Sow thistle

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Resource use efficiency in agroforestry intercropping

- Increased crop production in intercropping systems is mainly attributed to enhanced resource use:
  - Efficient use of growth resources such as solar energy, soil nutrients and water
  - Efficient use of recourses is achieved when maximum requirement for growth resources of the component of intercropping system (crop and tree) occur at different times. For example, in fruit trees agroforestry, crops (winter crops) are often cultivated when trees are at dormant stage. Therefore, the competition for growth recourses is minimized
- Intercropping utilizes water, nutrients, and radiation on the majority of the orchard space at various dimensions:
  - Vertically (plant size: tall, medium and short)
  - Horizontally (all planting spots are occupied)
  - Underground (deep-rooted and shallow-rooted plants)
  - Efficiently utilizes the soil moisture at different depths of soil
  - Effective utilization of leaching materials

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Resource use efficiency in agroforestry intercropping

Radiation exchange

- The majority of the incoming sunlight is absorbed by the earth's surface (51%) and the atmosphere (19%), with the remaining fraction (30%) being reflected by the atmosphere, clouds, and the earth's surface
- The incoming solar radiation is utilized by both trees and weed vegetation in agricultural farming systems, particularly in the orchards where the canopy of the tree does not fully cover the soil surface

The main goal of agroforestry intercropping is better utilize incoming solar radiation

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Resource use efficiency in agroforestry intercropping

Water Budget

Water in

- Rainfall
- Irrigation
- Upward flow from groundwater reserves

Water out

- Transpiration
- Evaporation
- Runoff
- Deep percolation

The main goal of agroforestry intercropping is to minimize water loss through evaporation, runoff and deep percolation

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Resource use efficiency in agroforestry intercropping

Nutrient budget

Input of nutrient

- Organic fertilizers
- Decomposition of plant material

Nutrient loss

- Leaching of minerals
- Loss of top soil through erosion

The main goal of agroforestry intercropping is to minimize nutrient loss through leaching and runoff

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Benefits of the intercropping agroforestry

- Intercropping system is reasonable not only for smallholders but also have enough potential to be applied at larger scales
- The benefits of any cropping system should be seen not only in terms of productivity and profitability, but also in terms of other important aspects that ensure cropping system sustainability

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Benefits of the intercropping agroforestry

The yield

- Yield is defined as a quantity of produce harvested per unit of land area
- Broader definition of yield includes a crop that gives byproducts, for example:
  - Cereal straw is fed to animals
  - Indirect benefits through adding more organic matter from the unharvested parts of the crop thus reducing the use of synthetic fertilizers
  - Firewood obtained from pruning fruit trees
- Besides environmental benefits, intercropping agroforestry system has two aims:
  - Provide a product of the right quality
  - Provide a sufficient quantity of the product required. Sufficient means producing enough quantity of saleable commodities to cover the cost of growing crop and leave a margin of profit

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Benefits of the intercropping agroforestry

The yield

- Growing two crops in same land at the same time will compete with each other for light, water and mineral nutrients. The yield of each crop will certainly be lower than when it is growing on its own
- The practice of intercropping is worth while only if the combined yield of the crop and tree is greater than the yield of either grown alone
- Generally, productivity and yield advantage of intercropping agroforestry system is determined by Land Equivalent Ratio (LER) which indicates the biological efficiency and yield per unit area of land as compared to mono cropping system.
- As reported by FAO: “The ratio of the area under sole cropping to the area under intercropping needed to give equal amounts of yield at the same management level. It is the sum of the fractions of the intercropped yields divided by the sole-crop yields.

$$\text{LER} = \frac{Yield\ tree\ agroforestry}{Yield\ tree\ monoculture} + \frac{Yield\ crop\ agroforestry}{Yield\ crop\ monoculture}$$

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Benefits of the intercropping agroforestry

The yield

- LER provides a reasonable measurement for evaluating the effectiveness of mixed cropping when products of both tree and crop are equally important to the farmer
- LER is less important and easy to interpret in the situation of fruit trees as main crop, intercropped with annual crops as second crop where intercropping system is designed to produce a full yield of main crop and some additional yield from a second crop

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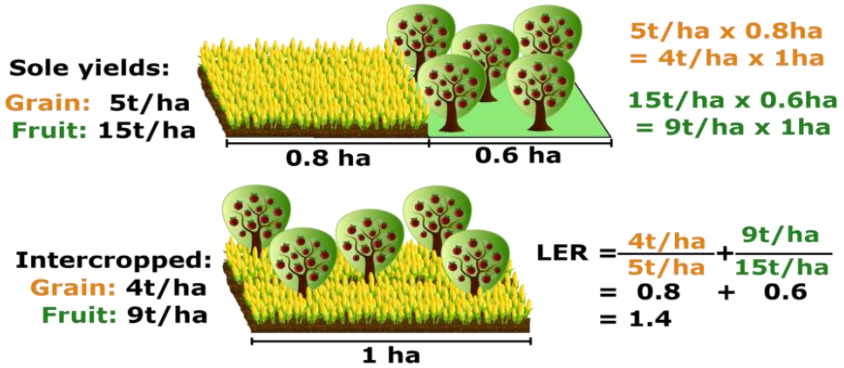
Benefits of the intercropping agroforestry

The yield

Example of calculation (Wikipedia)



Crop	Intercropped Yield, IY (kg/ha)	Sole Yield, SY (kg/ha)	Equivalent area (ha)
Grain	4,000	5,000	0.8
Fruit	9,000	15,000	0.6
Land equivalent ratio			1.4

- An interpretation of this result would be as follow: a total of 1.4 ha of sole cropping area would be required to produce the same yields as 1 ha of the intercropped system

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Benefits of the intercropping agroforestry

The yield

- The feasibility of introducing durum wheat and legume into olive orchard was studied in Southern France
- Results show that intercropping olive orchard with durum wheat rotated with legumes improves the profitability of fruit growing
- Over the period 2014–2017, the land equivalent ratio (LER) reached 1.81 (sum of the relative areas 0.62 for wheat and 1.29 for olives)
- Compared to natural grass cover, olive production is stimulated by intercropping through minimal tillage and improved soil fertility
- The associated durum wheat is an additional source of income in olive orchards with reduced yield

Photo by D. Kitsikopoulos and A. Pantera

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Benefits of the intercropping agroforestry

Soil fertility

- Mechanisms lead to the improvement of soil fertility and overall chemical soil quality as a result of intercropping agroforestry:
  - Nutrient uptake from subsurface layers and their efficient cycling: Trees capture nutrients leached from the topsoil and return them to the soil surface as litter
  - Biological nitrogen fixation
  - The role of crop and tree canopies in reducing the nutrient losses through runoff and sediments
  - Addition of organic matter through litter fall (dead and falling leaves, twigs branches). The increase in soil organic matter increases the activity of soil microorganisms and earthworm, which in turn breaks down plant residues and converts them into organic matter
  - The additional ground cover provided by the intercrop minimizes the impact of hazards such as heavy rains, strong winds and soil erosion, thereby reducing the decline in soil fertility and preventing degradation and loss of surrounding habitat

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Benefits of the intercropping agroforestry

Soil fertility

- Fine roots of the tree have a high decomposition rate and may be the major source of soil organic matter. But this contribution to soil fertility is relatively small in the early years of tree growth. Therefore soil fertility in agroforestry is a long term process. The obvious results will be evident only after several years of implementation
- Tree serves as a trap for nutrient accumulation from animals that seek shelter in their shade where they urinate or defecate

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Benefits of the intercropping agroforestry

Water management

- Mechanisms lead to the improvement of water retention as a result of intercropping:
  - Water retention depends mainly on soil composition and organic matter content: soils rich in clay and organic matter store three times more water than sandy soils. The biomass of crop and tree residues increase soil organic matter in the form of humus and thus increase water retention
  - Intercrop vegetation and tree litter protect the soil from crusting, and slow runoff
  - The roots of both crop and tree as well as earthworms maintain cracks and pores in the soil and therefore improve water infiltration

- **The yield of rainfed olive orchards entirely depends on rainfall, which is already highly variable from year to year. Water scarcity in semi-arid olive-growing areas is becoming more severe as climate change worsens**
- **Intercropping agroforestry system aims at a sustainable use of natural resources**

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Benefits of the intercropping agroforestry

Water management

- The tree litter and the remaining left after harvesting intercrop reduce the evaporation of water from the soil and shade the soil from direct sunlight and prevent the soil from getting too warm
- Complementary exploration of the soil profile by the root system of both tree and crop:
  - Crop and trees have different root system pattern that exploit a larger volume of soil and improve access to soil water
  - The deep fine roots of trees can absorb nutrients that leach below the crop, leading to nutrient cycling and to a decrease in pollutants entering into aquatic ecosystems
- Tree shade creates a beneficial microclimate for crops
  - Moderating temperature regime
  - Higher air humidity
  - Reduced evapotranspiration
  - Increasing soil moisture levels

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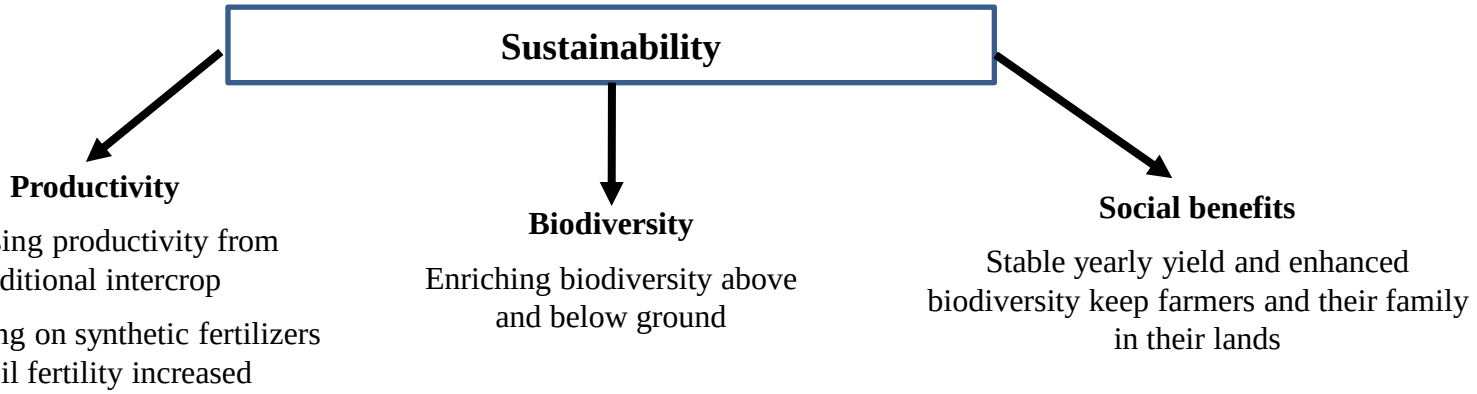
Benefits of the intercropping agroforestry

Sustainability

- Agroforestry is the deliberate integration of agricultural and forestry-based land-use systems in order to offer tree and other crop products while also protecting, conserving, diversifying, and sustaining essential economic, environmental, human, and natural resources



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Benefits of the intercropping agroforestry

Sustainability

- Economic functions
  - Agroforestry intercropping provides farmers with valuable, marketable and sustainable products such as firewood, fruit, cash intercrop, animal feed, and medicines. All these products provide a sustainable income to farmers as well as a sustainable benefit to the regional community
  - Farmers will have the option of diversifying their businesses by utilizing complex agroforestry
- Environmental functions
  - Agroforestry intercropping afford environmental benefits by improving soil fertility through fixing nitrogen from the air and recycling nutrient from the soil, hold moisture, reduce soil erosion and increase biodiversity of degraded lands
- Social functions
  - Agroforestry intercropping reduces the pressure on the natural forests and could provide valuable employment, business opportunities, and develop the village economy with environmental awareness
  - Farmers will have better access to education, security, healthcare and information through sustainable incomes from a variety of products

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Benefits of the intercropping agroforestry

Biodiversity

"Biodiversity refers to the variety of organisms, including microorganisms, plants, and animals in different ecosystems, such as deserts and/or forests" (Corsa Lok Ching liu et al. 2018)

Biodiversity is considered as a corner stone stability and basis of livelihood and sustainable development

- The plant diversity is one of the main reasons for increased biodiversity in agroforestry
- Adoption of Agroforestry intercropping with diverse trees/shrubs/crops may enhance biodiversity while providing additional income and aesthetic value

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Benefits of the intercropping agroforestry

Biodiversity

- The loss of biodiversity is evidenced by the extinction of species and the depletion of ecological interactions (ecological interaction in which those species are engaged)
- Main causes of biodiversity degradation:
  - Modernization and urbanization
  - Agriculture intensification
  - Overexploitation
  - Pollution
  - Global climate changes
  - Deforestation, forest fires
  - Hunting
  - Soil erosion

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Benefits of the intercropping agroforestry

Biodiversity

- Agroforestry intercropping system provides habitat and resources for various species and supports the entire soil food web:
  - Birds, bats, insect pollinators, crops, shrubs, trees, soil micro fauna and animals. Birds species contribute somewhat to the control of insects that cause damage to crops
  - Agroforestry intercropping system stimulates biodiversity within the soil (microbial, fungal and earthworms activities) through addition of compost or green manure and organic matter
    - These organisms play two major roles in the soil: decontaminating soils and improving soil health
    - Soil provides a source of food for soil microorganisms. In return soil microorganisms will trade other nutrients, such as nitrogen or phosphorous, to the roots of crops and tree. On the other hand, earthworms and arthropods eat fungi and bacteria

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Benefits of the intercropping agroforestry

Biodiversity

- Heterogeneous litter provided by agroforestry creates diverse micro habitats that contribute greater biological diversity in the soil
- Intercropping agroforestry as a diversified system supports the cultivation of multiple genetic species of a particular crop
- Intercropping agroforestry helps in the suppression of pests, weeds and diseases:
  - Development of a certain equilibrium between pests / diseases and their natural enemies
  - Crop rotation (if the orchards offer the possibility of annual crop rotation) is an important way of controlling populations of nematodes, parasitic soil fungi and other pests and diseases

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Benefits of the intercropping agroforestry

Biodiversity

- The role of intercropping agroforestry in biodiversity enhancement:
  - Spontaneous colonization by plants taking place in abandoned agroforestry systems may lead to the formation of more complex ecosystems
  - A well-designed agroforestry system that provides high productivity and sustainability serves as a model for encouraging the conversion of natural habitats into agroforestry systems rather than modern systems
  - Agroforestry helps conserve biological diversity by providing other ecosystem services such as erosion control and water recharge, thereby preventing the degradation and loss of surrounding habitat
  - Intercropping practices aiming at reducing the use of inorganic fertilizers, pesticides and herbicides promote higher biodiversity
  - Reduced or no-tillage favors greater diversity as tillage destroys fungal mycelial networks

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Benefits of the intercropping agroforestry

Biodiversity

- Agroforestry serves as a corridor between the forest and the other lands and thus serves as a habitat outside of protected forests
- The esthetic value of landscape and the conservation of biodiversity can be more pronounced when establishing agroforestry intercropping system adjacent to forest

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Benefits of the intercropping agroforestry

Biodiversity

- The esthetic value of landscape and the conservation of biodiversity can be more pronounced when establishing agroforestry intercropping system adjacent to forest

Photo by Lisa Radinovsky

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Benefits of the intercropping agroforestry

Less use of synthetic fertilizers

- The use of synthetic inorganic fertilizers reduces soil biodiversity while reduced or no-tillage favors greater diversity as tillage destroys fungal mycelial networks. These impacts can cause shifts within the soil and affect all functions
- Reduction or stopping use of synthetic fertilizers under intercropping agroforestry system is achieved by the efficient nutrient uptake by crops through the design and management of land use systems
    - In an intercropping system, the competition for nutrients among the crop species can be reduced by selecting appropriate crops with dissimilarity in nutrient needs, root morphology and time of peak requirements
    - Root architecture is modified by the nutritional status of the soil: plants growing in limiting P environment develop cluster roots and increase the number of root hairs and lateral roots to increase the root surface area and thereby acquisition of P
        - Lupinus sp. can encourage the production of cluster roots, which release phosphorus solubilizes like citrate and malate in sufficient quantities to reduce the rhizosphere pH, hence improving phosphorus transport and plant intake

Benefits of the intercropping agroforestry

Less use of synthetic fertilizers

- Reduction or stopping use of synthetic fertilizers under intercropping agroforestry system is achieved by the efficient nutrient uptake by crops through the design and management of land use systems (Continued)
  - Solubilization of nutrients that are not easily available to plants through the root exudates and acid secretions:
    - Organic acids such as malate and citrate are important compounds exuded to mobilize inorganic P in soils
    - Due to the deficiency of P in the soil, some crops such as alfalfa, spinach and radish increase the influx of organic ions
    - Intercropping olive orchards with graminaceae crops that exudate chelating agents called "phytosiderophores" (PS) make Fe^{3+} and Zn^{2+} available for the neighboring olive tree in calcareous soils

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Benefits of the intercropping agroforestry

Less use of synthetic fertilizers

- Olive mill wastes (OP: olive pomace, and OMWW: olive mill wastewater) may be used directly as a nutrient-supply amendment in olive orchards, or may be composted with other organic materials obtained from tree prunings and crop residues for future use in the field
- Periodic mowing of the crops and tree residues provides the soil with organic matter and thus minimizes the need for synthetic fertilizers
  - 0.6-2.1 ton/ha per year of humus release 80-100 kg of N, 20-25 kg of P and 130-150 kg of K
- Using of animal manure (solid and liquid animals dejections mixed with straw)
- The leguminous plants are less reliant on synthetic fertilizers. It has been estimated that worldwide, biological nitrogen fixation produces roughly 200 million tons of nitrogen annually
  - Nitrogen fixation can be considered an alternative method to applying synthetic fertilizers. Especially that more than half of the added synthetic N fertilizers are lost through different pass ways

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Benefits of the intercropping agroforestry

Better income

- Traditional olive groves are usually of low production due to various reasons
  - Low tree density
  - Olive tree were historically growing on soils with low fertility
  - Very old trees
  - The alternate bearing phenomenon
  - Small holdings
  - Fluctuation in market prices
- These limiting factors led to an intensification of olive cultivation
  - New orchard are established on flat fertile soil
  - Adopting modern varieties
  - Irrigation
  - Input of synthetic fertilizers
  - Weed control by repeated tillage and herbicide use
  - Mechanical harvest

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Benefits of the intercropping agroforestry

Better income

- For increasing production, input cost was also increased
- Despite the increasing of production, the modern agricultural systems don't always ensure stable profitability
- Many farmers have started adopting intercropping as an alternative to intensive farming to ensure better income
- Intercropping came to take advantage of the empty spaces within the orchard, and showed that it could be a solution to address the low productivity of traditional olive groves, the alternate bearing and the increasing volatility of olive oil market prices

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Benefits of the intercropping agroforestry

Better income

- The primary goal of any agricultural application, particularly intercropping, is to obtain a consistently higher income
- Agroforestry practices can recoup initial costs relatively quickly due to the income generated from intercropping adoption
- Intercropping as a diversified system increases the potential for economic profits by providing annual and periodic revenues
- However, market and crop price fluctuations influence the productivity of an agroforestry intercropping system (Income is governed by a wide array of psychological, cultural, input, costs and market factors). In addition, crop-tree intercropping system demands more labor input in terms of field management, than a mono-cropping system
- In sum, intercropping as a complex system should be organized to make better use of available resources while maintaining the lowest possible production cost

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Benefits of the intercropping agroforestry

Better income

Direct benefits		Indirect benefits				
Main products	**Byproducts**	**Shading and reduction of wind velocity**	**Suppression of weeds**	**Control of erosion**	**Improved moisture retention**	**Increase in soil organic matter**
Fruits, grains, and vegetables	Wood for fuel, building material, and stakes	Reduction of plant damage	Reduction of herbicide use	Reduction of fertilizer use		
	Remnants of tree and crop as fodder					
	Products used in medicine					

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Better income

Case study “Olive trees intercropped with legumes and cereals”

Olive trees intercropped with a mixture of barley and common vetch
Photo by Dr. Peter Moubarak

Better income

Case study "Olive trees intercropped with legumes and cereals"

- This study was carried out in olive orchard in the premises of the State Rural Prison in Kassandra Chalkidiki, in December of 2014
- It comprised three treatments:
  - Olive trees + barley
  - Olive trees + a mixture of barley and common vetch
  - Control, olive trees alone
- The mixture was harvested for hay and the barley for grain
- The three year trial demonstrated an impressive growth of olive trees, and higher production of olives to that previously attained
  - The results showed that the accumulation of the biomass is unaffected by the position relative to the tree
  - Olive tree had a positive effect on seed yield as the number of seeds was higher near the tree.
  - Total hay and seed production were higher in the second and third years of the experiment

Better income

Case study “Olive trees intercropped with Gundelia”

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Better income

Case study ”Olive trees intercropped with Gundelia”

- Gundelia is a perennial plant native to the eastern Mediterranean and the Middle-East
- Traditionally the sturdy Gundelia stems and flower buds are used to make favorite dishes like stews, soups or fried eggs
- The cooked young stems are said to taste like a combination of artichoke and asparagus
- Olive orchards in Palestine are intercropped with Gundelia due to its high profitability

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Better income

Case study ”Olive trees intercropped with Gundelia”

- Many farmers in Palestine's West Bank intercrop their olive groves with the Gundelia crop, which provides economic benefits to rural communities
- Reports from many farmers indicate that one acre of land produces about 4000 kg of Gundelia flowers and stems
- One of the farmers in Immatain village, who planted the Gundelia in his olive orchard acknowledged the economic and social benefits of this cultivation, which efficiently exploits the empty spaces within their orchards
  - In the third year, one ton of Gundelia flower and stems were harvested from 1000 m^2
  - Several employment opportunities were created as a result of the project
- Weed control was the major constraint of this cultivation

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Better income

Case study “Wild asparagus in olive orchards”

- Wild asparagus is a perennial crop that is popular in the Mediterranean diet
- Wild asparagus is tolerant to shade, cold, and drought and is appropriate for planting in organic or untilled olive orchards
- Wild asparagus seedlings can be planted at 33 cm spacing along rows of olive tree to facilitate machinery for olive pruning and harvest. In this case, 4000 to 5000 seedling are needed per hectare
  - From the second or third year after planting asparagus will produce 50–100 kg of harvestable spears each spring (March to May depending on local climate)
  - With the planting density of 5000 plants/ha, the yield can be 250–500 kg per hectare
- If olive tree is manually harvested, the seedlings can be planted in inter row area at 33 cm spacing and 1 m row. In this case 30000 plants are needed per hectare
  - With 30000 plants/ha, the yield can be 1500–3000 kg per hectare

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Better income

Case study “Wild asparagus in olive orchards”

- Asparagus is usually attacked by few pests
- The main constraint of planting asparagus within olive orchards are:
  - High level of hand labor is required for harvesting and weed control
  - Marketing fresh and perishable asparagus spears is a difficult task that must be carefully assessed
- Advantages:
  - Intercropping asparagus within an olive orchard increases the productivity of unit of land, while requiring few extra inputs
  - The process of weeding, fertilizing and possibly irrigating the asparagus can benefit the olive trees without additional costs
  - With increasing volatility in the market prices for olive oil and the uncertainty associated with climate change; crop diversification can protect farmers from extreme crop failures. It is unlikely that both crops will completely fail in the same year

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Better income

Case study “olive tree intercropped with chickpeas”

- Chickpea (*Cicer arietinum* L.) is considered as high quality food for humans and animals
- Chickpea is easy to cultivate, requires little management, and generally has low maintenance costs
- Low water demand is the main characteristic of chickpea
- The cultivation of chickpea in olive orchards provide farmers with additional income
- Chickpea is a nitrogen fixing crop that benefits the farmer by reducing the need for expenditure on nitrogen fertilizers while also protecting soil and water from pollution

Photo by Dr. Anastasia Pantera

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Better income

Case study “olive tree intercropped with chickpeas”

- A trial was conducted in Molos, Central Greece, in a 67 year-old olive grove of “Kalamon” and “Amphissa” varieties. The spacing between the trees was 10 m
- Treatments
  - Olive tree+ chickpea, olive tree + oregano, olive tree alone
- The best timing for seeding is between late February and March for lower altitudes. However, at higher altitudes, it can be sown up to late April
- Results
  - In the first year of the experiment, the production of olive in olive + chickpea treatment did not differ significantly from control. The yield of chickpea was low
  - But in the second year, the yield of the chickpeas was very successful with production reaching 2600 kg/ha. Oil production and quality was excellent and it was the same for edible olives
  - Intercropping oregano with olive trees did not show a good result due to the late date of establishment and the limited water it received after planting

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Limitations of intercropping agroforestry

- Supportive policies for the intercropping agroforestry are still insufficient
- Successful agroforestry systems necessitate a thorough understanding and assessment of the complexities of such a multi-dimensional production system
- Management of intercrop having different cultural practices
- Carrying out intercultural operations such as mechanization; for example, the existence of intercrop during the fruit maturity of the tree makes harvesting difficult
- Allelopathic effect of some intercrops
- Yield decreases as the crops differ in their competitive abilities
- Beside being host of some beneficial insects, intercrops can serve as alternate hosts for a variety of pests and diseases
- Intercropping is a labor-intensive practice

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